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Electricity sector in Tunisia: Current status and challenges—An example for a developing country

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ABSTRACT

During the last decade, Tunisia evolved in an extremely difficult energy context characterized by the stabilization of the resources in hydrocarbons, the increase of the energy consumption and the increase of the price of oil ($147 the barrel in July, 2008), imposing on it to mobilize more to meet several challenges in terms of outside energetic dependence for the generation of electricity and the reduction of greenhouse gases. This policy allowed the reduction in the rate of growth of energy intensity of the country. This article presents a review about renewable and conventional energy resources, electricity consumption and production and the policy adopted by the country for energy conservation and the promotion of renewable energy.

Contents

1. Introduction

The fourth report of the intergovernmental group of experts on the evolution of the climate confirmed that the climate change is henceforth irrevocable and that human activities are very probably the cause. It is estimated that the average temperature at earth's surface has risen by 0.74 °C since a century [1]. Problem of global warming requires a wider international participation in the efforts of reduction of greenhouse gas emissions. To limit the fatal consequences of global warming, the increase of the temperature does not have to overtake 2 °C by the end of the century [2].

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The scale of climate change makes from the energy conservation and the resort to the clean technologies an absolved priority for the reduction of gas emissions from the energy sector.

The clean development mechanism was established by the Kyoto protocol. That mechanism of flexibility facilitates the investments of reductions of greenhouse gases in the developing countries and helps industrial nations to respect their commitments of reduction and limitation of greenhouse gases. In this respect, in spite of the relatively low level of emissions in Tunisia, the clean development mechanism offers an opportunity to exploit its potential of reduction of greenhouse gases in the sector of energy, favor the investment in the respectful technologies of the climate and adopt a growth mode more economic in energy and in greenhouse gases reject. Tunisia is one of the first developing countries having adopted a policy of energy conservation from the middle of the 1980s. Since 2005, important measures strengthened this policy with the adoption of a new law on the energy conservation and the creation of a national fund of energy conservation.

This policy strengthened by the promulgation of the law of 2nd August 2004 on the energy conservation amended by the law of 9th February 2009 which opens the way to the auto production of electricity by renewable energy.[1]

2. Tunisia position

Tunisia is a small country located in North Africa, between longitudes 8° and 12° east and latitudes 30° and 37° north. It borders in the west with Algeria, in southeast with Libya and in the north and east with the Mediterranean Sea. It covers an area of 163,610 km^2 and has a population of 10,432,500 inhabitants.

The Tunisian economy is diverse and based on agriculture (farming), manufacturing, oil production and tourism. The World Economic Forum ranked Tunisia as the most competitive economy in Africa and the 40th in the world [3].

The north of Tunisia is characterized by a Mediterranean climate, with hot and dry summers, and mild and relatively rainy winters. The center of Tunisia is influenced by the Mediterranean and the Sahara has a semi-arid climate, characterized by relatively high temperatures and modest rainfall between 200 and 400 mm/year. The rest of the country witnesses a desert arid climate characterized by high temperatures as well as important amplitudes. Due to this position between the tempered regions of the northern Hemisphere and the inter-tropical regions, Tunisia is particularly vulnerable to climate change [4].

3. Availability of renewable energy sources

Tunisia is well equipped in renewable resources such as the solar one and the wind one, but it also has a rather interesting potential in other applications like the geothermic resources, the biomass and hydraulics.

3.1. Solar energy

The climate of Tunisia is characterized by a total insulation period of 3500 h/year and 350 sunny days per year. The global solar radiation intensity varies between 4.5 $kWh/m^{-2}\,d^{-1}$ in the north to more than 6 $kWh/m^{-2}\,d^{-1}$ in the south [9], see Fig. 3.



Fig. 1. Water desalination station of Ksar Ghilène [6].

The solar radiations are exploited at the thermal level, for the heating of water and at the electric level for electricity production in isolated areas. Thanks to a PROSOL program launched in 2005, the installed surface of solar water heating reached 400,000 m^2 in 2009, against 123,000 m^2 in 2004. Till the end of 2008, the use of the photovoltaic solar energy has allowed the electrification of more than 11,500 isolated homes and more than 200 rural schools, the street lighting of certain number of beaches and urban parks, the installation of more than 70 solar stations of pumping of water with the aim of supplying the inhabitants in drinking water and the installation of a water desalination station with a capacity of 15 m^3/J supplied with a 10 kW photovoltaic station in Ksar Ghilène [22] (Figs. 1 and 2).

3.2. Wind energy

Tunisia has a significant wind energy potential and may reach as much as 900 kWh/m^2/year [7]. Three zones of wind potential can be identified by examining the map of wind distribution over the country, Fig. 4. The first group covers Thela, Klebia, Bizerte, Monastir, Tunis-Carthage and Elborma characterized by a good wind potential, of which the annual mean speed lies between 3.6 and 4.8 m/s and the available energy varies from 537 to 893 kWh/m^2/year, the second covers Ramada, Gabes, Jendouba, Djerba, Kairouan, Sfax and Medenine characterized by an average wind potential, of which the annual mean speed lies between 2.7 and 3.6 m/s and the available energy varies from 268 to 433 kWh/m^2/year and the third group covers Tabarka, Gafsa, Sidi-Bouzid and Tozeur characterized by a low wind potential, of which the annual mean speed lies between 2 and 2.9 m/s and the available energy varies from 128 to 227 kWh/m^2/year [8].

The first wind power station of 19.26 MW in Tunisia was created in 2000 in Sidi Daoud in the north east of the country.



Fig. 2. Pumping station of Zoumit [6].

[1] The establishment or the grouping of establishments practicing in the industrial, agricultural or tertiary sectors and which produces some electricity from renewable energies for its appropriate consumption, benefits from the right of the transport of the electricity so produced by the national electricity network up to its points of consumption and the right of sale of the surpluses of the electricity exclusively to the Tunisian Electricity and Gas Company within the limits of 30 percent of the electricity produced annually [5].

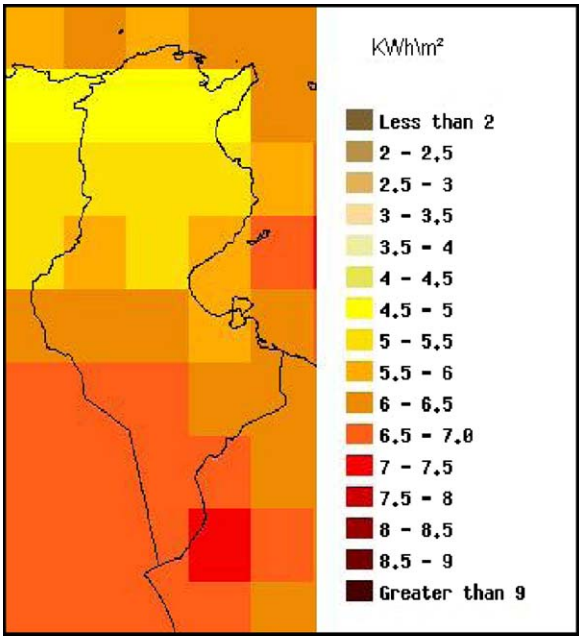


Fig. 3. Distribution of the solar radiation.

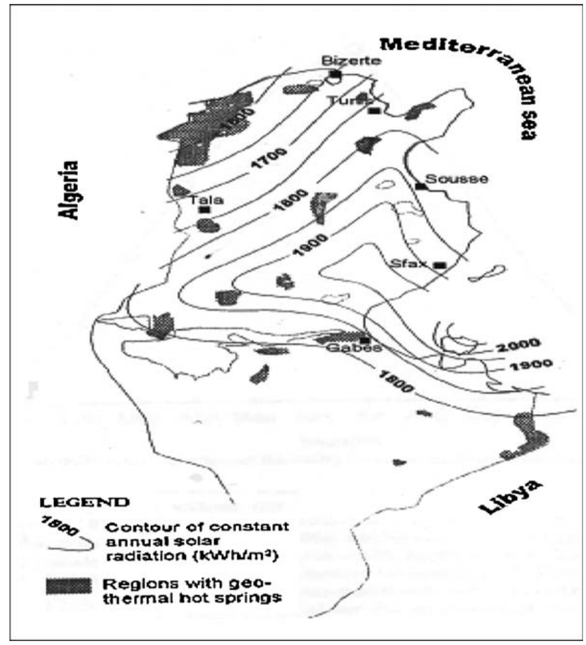


Fig. 5. Map location of region with geothermal hot spring [9].

It allows an energy contribution of 40 GWh per year and a profit of 10 ktoe per year (ktoe: thousand tons of oil equivalent), Fig. 6. Currently, an extension of the capacity of Sidi Daoud to 55 MW is done and three wind farms with a total capacity of 120 MW will be built by 2010 in Bizerta, Jendouba and Beja. Also, several wind turbines for small power drivers (powers between 400 W and 3000 W) are installed in the country for different applications (water pumping, rural electrification, refrigeration). Tunisia's strategy of wind energy is to increase production to 175 MW by 2010, that is, 4.2% of total electricity generation capacity [21].



Fig. 4. Map of Tunisia [8].

3.3. Geothermal energy

Most geothermal resources are recognized as geothermal water springs. They have been used for bathing and therapeutic treatments (e.g. in Korbous, EI-Hamma and Hammam-Zriba) and for heating agricultural greenhouses in some cases. It is transferred to conventional desalination plants such as the RO plant in Gabès, in some other cases. Fig. 5 shows the distribution of the geothermal resources through the country [7,9].

Geothermal energy allowed creation, in the south of the country, of 380 ha under greenhouse for the production of early products. It is also envisaged to arrange 300 ha in Kébili, Tozeur, and Gabès for the production of 48 thousand tons early products intended for export [20].

3.4. Biomass energy

In Tunisia the development of the use of the biomass is posed more in terms of environmental protection than of extension of the energy capacities. In 1997, the wood energy consumption is estimated at approximately 17% of the total national energy consumption, either 0.9 Mtoe per year (Mtoe: million tons of oil equivalent), and it is located essentially in rural area for the preparation of traditional bread. The forest resource is limited and



Fig. 6. Sidi Daoud wind farm [8].



Fig. 7. Metal lids for hearths of traditional bread.

consumption must be rationalized in order to avoid its harmful effects, and in particular deforestation.

From the end of the eighties, a distribution program of the metal lids for hearths of traditional bread cooking in medium rural was put by the National Agency of Renewable Energies (ANER), Fig. 7. Currently 16,000 lids were diffused near the rural households allowing a saving in firewood and contributing to the conservation of forests [22].

Biogas comes especially from the valorization of domestic waste, in accompaniment of the program of opening of the controlled discharges. Among the most significant discharges that it will be necessary to develop in the short term is that of Jebel Chakir which absorbs to it only 40% of the household refuse of the country. The organic quantities of waste produced on a national scale are estimated at approximately 6 million tons per year [10].

The strategy adopted by the ANER dice the middle of the nineties was to turn to the valorization of this waste by the production and the use of biogas, primarily for the production of electricity, Fig. 8. Currently, the realization consist of the establishment of 50 family units of production of biogas in the area of the north-west, the realization of an industrial unity of production of biogas from poultry droppings, realization and exploitation of 10 controlled discharges and the launch of an experimental project of production of biodiesel using worn vegetable oils with a starting capacity of 5000 tons per year [22,10].

3.5. Hydraulic

An important hydraulic potential can be found in the northern part of the country and has been exploited for electricity production. The hydro-electric power stations current are in El Aroussia, Nebeur, Fernana, Kasseb, Sidi Salem, Bouhertma and Sejnane with a total power installed of 62 MW. It allows a production of 38 GWh in 2008, which corresponds to a reduction in fuel consumption of 22 ktoe.



Fig. 8. Biogas conversion and energy production Station in Choutrana (Northern Tunis) [10].

4. Conventional energy

The national hydrocarbon resources increased by 37%, passing from 6 Mtoe in 1987 to 8.2 Mtoe planned for 2009, this returns to the number of drillings which reaches 42 in 2009 against 14 into 2005.

4.1. National availability of gas

Because of its availability and its environmental qualities, the natural gas is consolidating its position in the cover of the national demand for primary energy. During 2008, the national availabilities of gas knew an increase of 11% compared to 2007 (4770 ktoe in 2008 against 4300 ktoe in 2007). This increase is explained by the exploitation of the new gas layers (of Chergui and Jebel grouz), the increase in the total Algerian gas returning in a Tunisian state due to the startup of the new compressor plants of Korba and Sbeitla and the increase in the availabilities of gas of the south. The total uses of gas recorded a progression of 10% passing of 3853 ktoe in 2007 to 4337 in 2008, see Fig. 9. This increase is due to the rise of consumption of the centers of electric productions and the average customers pressure and high pressure. The STEG feeds, at the end of October 2009, 457,000 customers. In 2008, 4244 ktoe were consumed, including 74% used for electric production, 10% for industry (HP) and 16% for residential one the tertiary sector. The distribution grid system of natural gas has more than quintuplet, passing 1849 km in 1987 to 11,302 km in 2009 [18].

4.2. Oil sector

The Tunisian oil reserves are modest 308 million barrels. The majority of these reserves are localized in the Gulf of Gabes and the Ghadames Basin in the southern part of the country. The majority of the oil is produced from six main concessions: El Borma, Ashtart, Oued Zar, Adam, Didon and Miskar [11]. In 2007, Tunisia produced an average of 97.6 thousand barrels of crude oil per day, 0.11% of the world total and a 40.1% change compared to 2006 [12].

The Tunisian company of oil activities (Entreprise Tunisienne d'Activités Pétrolières: ETAP) is the state owned petroleum company, its mission is to manage the oil and natural gas exploration and production activities on behalf of the state, while, the national company of the distribution of petrol (Société Nationale de Distribution de Pétrole: SNDP) is the national distribution and marketing company.

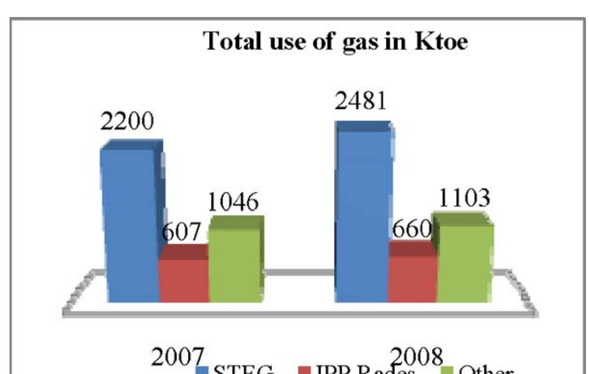


Fig. 9. Evolution of the uses of gas.

5. Electricity consumption and production

The majority of the electricity used in Tunisia is produced locally by The Tunisian Electricity and Gas Company (STEG), which as the national electric utility, and is responsible for electricity generation, transmission, and distribution, as well as natural gas transport and distribution. In 2002, the first Independent Power Plant (IPP) was created with a 471 MW combined cycle (natural gas and diesel-fired) and went online at Rades. It is owned and run by the Carthage Power Company. In July 2003, Tunisia's second IPP with a 30 MW plant, began commercial operations and operated by CME Energy [17].

The electrical network in Tunisia serves almost all the population. In 2008, the total rate of electrification of the country reached the level of 99.5% (urban 99.8% and rural 99%) [18]. The number of subscribers to the electrical supply network has triplet passing from 1.1 million in 1987 to 3 million in 2009. The number of households connected to the network of natural gas multiplied by more than 13 times from 40,000 in 1987 to 530,000 in 2009.

Fig. 10 illustrates the evolution length of the grid system of electricity in km between 2005 and 2008.

In 2009, the request of primary energy was 3092 kt marking a decline of 2.8% with regard to that of the same period of year 2008. This decline is mainly due to the decrease in demand for petroleum products of 6.7% passing of 1695.6 kt at the end of May 2008 to 1582.3 kt at the end of May 2009. In terms of electricity, the consumption progressed of 0.1% that is 4638 GWh at the end of May 2009 against 4634 GWh at the end of May 2008. This increase is essentially due to the increase of the low voltage consumption of 3% at the end of May 2009. However, high and medium voltage consumption decreased, at the end of May 2009, with respectively 2% and 2.2% [13]. Fig. 11 shows the distribution of electricity

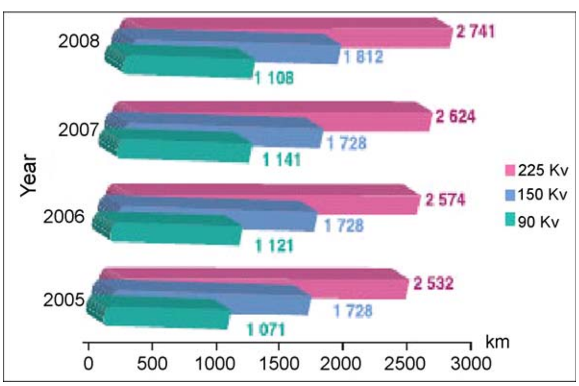


Fig. 10. Evolution of the grid length [18].

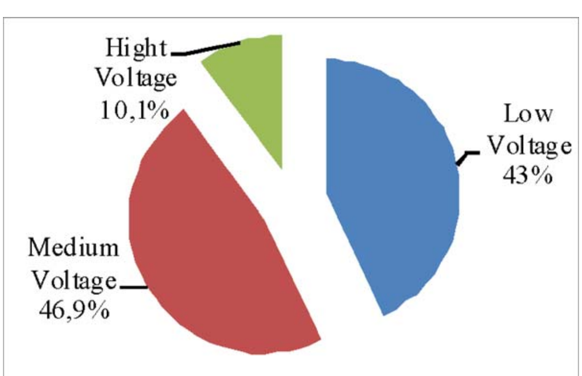


Fig. 11. Distribution of electricity consumption per level of voltage [18].

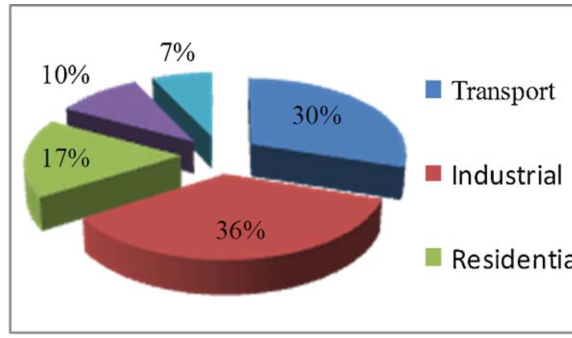


Fig. 12. Energy consumption by sector [14].

consumption per level of voltage. The share of industry sector in primary energy consumption was 36% followed by transport 30%, residential 17%, tertiary 10% and agriculture 7%, Fig. 12.

The national production of electric power injected into the grid per the STEG, IPP and purchase near the own producers amounted to 13,757 GWh in 2008 against 13,146 into 2007, recording an increase in 4.6% compared to 2007. The production at the boundaries of power stations STEG reached 10,250 GWh in 2008 against 10,036 GWh into 2007, which corresponds to a growth rate of about 2.1%. Fig. 13 presents the distribution of the national production of energy per type of equipment and the national power installed.

The installed capacity of the equipment of the national park of production did not record change into 2008 compared to 2007. The STEG has a park of production diversified and distributed of 23 manufacturing units (gas turbine, vapor turbines, combined cycles, hydraulic, wind turbine) of an installed power capacity about 3313 MW into 2008. Table 1 presents the evolution of the installed capacity in MW by types of equipment between the 2006 and 2008 [18].

On the energy level, Tunisia passed from a surplus country (3 Mtoe at the beginning of the eighties) as an importer net of energy since 2001, see Fig. 14. This adverse balance is said to the decline of oil production of the country and the growth of the national energy demand (4.1% of average growth per year for the primary request for energy) [16].

In 2008, the consumption of the fuel for electricity production increased by 5% with regard to 2007. It reaches 3304 ktoe during 2008 against 3147 ktoe in 2007. Table 2 illustrates the consumption of fuel by the STEG and IPP for the electricity production between 2007 and 2008. We notice an increase of 12.7% of the consumption of gas. It is explained by the growth of the national demand, on one hand, and decline of 51.6% of the consumption of heavy fuel oil, on the other hand [18].

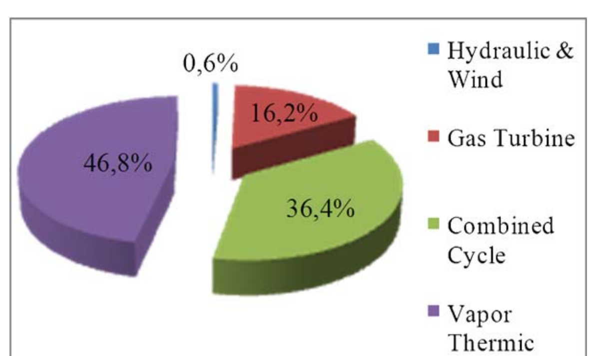


Fig. 13. Distribution of the national energy production per type of equipment [15].

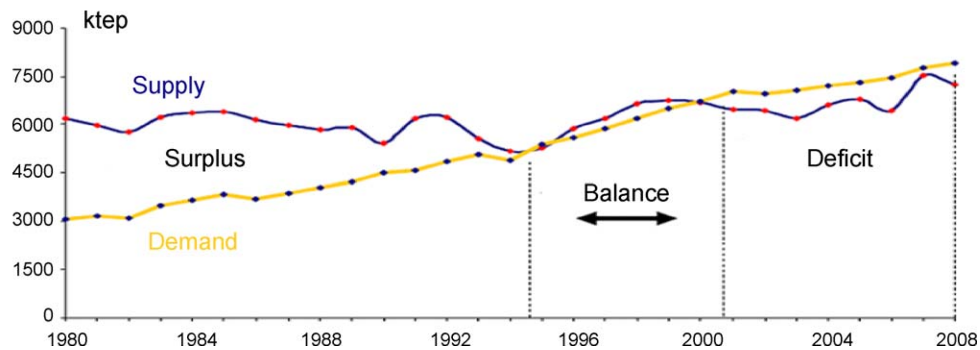


Fig. 14. Evolution of the resources and the energy demand in Tunisia [14,16].

Table 1
Evolution of the national power installed capacity in MW.

	2006	Part %	2007	Part %	2008	Part %
STEG						
Type of equipment						
Vapor thermal	1090	34	1090	33	1090	33
Combined cycle	364	11	364	11	364	11
Gas turbine	1163	36	1280	38	1280	38
Hydraulic	62	2	62	2	62	2
Wind	19.26	1	19.26	1	19.26	1
Total	2698	84	2815	85	2815	85
IPP I	471	15	471	14	471	14
IPP II	27	1	27	1	27	1
Total IPP (independent power)	498	16	498	15	498	15
Total national power	3196	100	3313	100	3313	100

The energy conservation and the promotion of the renewable energies appear among tracks privileged by public authorities to face the challenges met in the energy sector. For that, Tunisia adopted a policy of energy conservation from the middle of 1980s consolidated by an institutional framework governing the operation of this policy and that by the creation in 1985 of the agency for the energy conservation (AME), which became the national agency of the renewable energies (ANER) in 1988 then the national agency of energy conservation (ANME) in August 2004. Its mission consists in implementing the policy of the state in the field of energy conservation and the study of the promotion of energy efficiency, renewable energies and the substitution of the energy.

6. National energy conservation policy

The Tunisian state has set up since more of 20 years a policy of energy conservation and the promotion of renewable energies. Within the framework of this policy, a national program of energy conservation was set out for the period 2005–2007, accompanied by the creation of the national energy conservation fund. This fund is intended to support the actions of energy efficiency, the development of the natural gas and the renewable energies. This program ended in an energy saving of 700 ktoe in 2007, that is, 8% of the national consumption and a reduction of the greenhouse gas emissions of 2.4 Mte-CO_2 [14].

Furthermore, the new four-year program for the energy conservation concerning period 2008–2011 was set out for main objectives, the reduction of request in energy by 20% for 2011 and the increase of the renewable energies to reach 4% of the demand on electrical energy [14]. Fig. 15 presents the evolution of the energy demand with and without energy conservation between 2004 and 2011.

So, and to strengthen the national effort in the renewable energies beyond 2011, Tunisia drew up the Tunisian Solar Plan (TSP) [14], which integrates the wholes range of the fields of energy efficiency and the renewable energies. The total cost is estimated at 3600 Million Tunisian Dinars (MTD), which corresponds to 2770M$. The developers of this big project are the public sector, the private sector and the international cooperation.

The expected energy saving, once the projects were realized, would be in the order of 660 ktoe a year, which corresponds to 22% of the global reduction of the national energy consumption in 2016. The quantity of CO_2 avoided by these projects is considered at 1.3 million tons a year allowing a CDM return of 260 MTD, that is 200M$, over 10 years.

This solar plan confirms the Tunisian ambition to become an international hub for industrial and energy production and exportation in renewable energy. It covers the period 2010–2016 and groups together 40 projects distributed in 5 chapters classified by field of energy activity [19]:

6.1. Solar energy

The solar project is constituted of a thermal solar and an electric solar. With regard to the electric production, construction of decentralized photovoltaic installations connected to the network of a 15 MW total capacity, equipment of 200 agricultural farms with photovoltaic water pumping systems intended for irrigation with the aim of a large-scale later dissemination, electrification of domestic farms and small projects in rural middle by photovoltaic and wind turbine installation of a 3 MW total capacity, realization of the street lighting installations based on the photovoltaic solar energy of total power of 500 kW, equipment of 100 petrol stations with photovoltaic solar energy systems for electricity self-production, realization by the STEG of a concentrated solar power for the electricity production of 25 MW capacity integrated to a combine cycle of 150 MW capacity, realization by the private sector in partnership with the STEG of concentrated solar power plants for the electricity production of 75 MW capacity intended

Table 2
National consumption fuel for the electricity production.

Fuels	2007	2008	Variation 2007/2008	Participation %	
				2007	2008
Natural gas	2200	2480	12.7	69.9	75.1
Heavy fuel	339	164	−51.6	10.8	5
Fuel-oil	0.5	0.4	−20	0	0.01
Total STEG	2540	2644	4.1	80.7	80
Natural gas IPP	607	660	8.7	19.3	20
Total	3147	3304	5	100	100

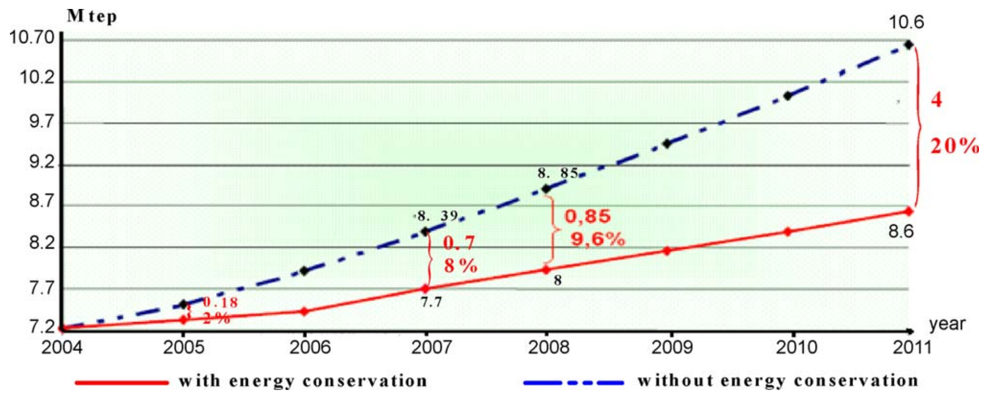


Fig. 15. Evolution of the energy demand between 2004 and 2011 with and without energy conservation [14].

for exportation, construction of a 40 MW capacity solar-gas combine concentrated solar power plant (30 MW gas and 10 MW solar) in the oil base of El Borma by the Tunisian-Italian oil company (SITEP) in partnership with the STEG, realization of the photovoltaic power plants of total capacity 10 MW connected to the national power network by the private sector in partnership with the ANME and the STEG, construction of a photovoltaic power plant of 10 MW capacity connected to the national power network by the STEG, and finally, construction of a plant for the manufacture of photovoltaic panels by the private sector of a minimum annual production capacity of 14 MW. With regard to the thermal production, six projects are scheduled between 2009 and 2014, which group the heating of the water by solar energy in the residential, tertiary and industrial sector, the solar cooling and the solar drying in the food-processing industry.

6.2. Wind energy

The first project will be realized by the private sector in partnership with the STEG and the ANME, and consists in self-production of 60 MW of electricity from the wind energy for the supply of the big power consuming facilities. The second project will be realized by the STEG for the production of 120 MW of electricity from the wind energy in the region of Bizerte. The third project will be realized by the private sector and consists in the construction of a windmill farm of a total capacity of 100 MW, and is intended for exportation to other countries interested by this clean energy.

6.3. Energy efficiencies

Seven projects are scheduled between 2009 and 2016, realized by the private sector and the public sector and which are respectively: replacement of 400,000 refrigerators that are over 10 years old by refrigerators energetically successful of classes 1 and 2, realization of energy positive sections of buildings for a total area of about 15,000 m^2, installation of 11 million m^2 of thermal insulations area of buildings roofs, dissemination of 5 million low consumption lamps, training of drivers in the economical driving behavior, installation of system of follow-up of the vehicles fleet of the public companies, and finally, development of a program of energy efficiency in the industrial sector.

6.4. Studies and implementation of the plan

The projects which will be realized within the framework of this fourth chapter are respectively: creation of an international upper center for advanced training in renewable energies, energy efficiency and international laboratory for solar energy technologies, construction of a pilot experimental photovoltaic power plant at the center of high-tech city of Borj Cedria of a 250 kW power capacity, creation of a company of study, realization, exploitation and maintenance of the renewable energy installations called STEG renewable energy, realization of a strategic study on the electric production of solar and wind origin, and finally, the implementation of a management unity of the Tunisian solar plan.

6.5. Other projects

Seven projects will be realized by the private sector between 2010 and 2016, which are respectively: implementation of two power plants production from biogas of a total capacity of 14.5 MW, production of the electricity by optimization of landfill gases of Djebel Chakir for a 10 MW power capacity, self-production of electricity by optimization of organic wastes in to biogas, installation of a sub-marine connection between Tunisia and Italy by two cables of a total capacity of 1000 MW within the framework of ELMED project and the deprived production of 100 MW solar energy for the export to Italy, electrification of the city of Nafta (in the South of Tunisia) by the renewable energies so to convert it in a city totally independent from the public network, construction of renewable energies development pole in the region of Zarzis, and finally, energy optimization of the reclamation project of the train station of Sousse.

7. Conclusion

Tunisia is one of the few developing countries to have taken into account viable development energy in its strategy and set up policies and measurements in favor of energy conservation and the reduction of dependence on fossil fuels for the generation of electricity. The Tunisian solar plan is one of the greatest challenges in the history of Tunisian energy. Once realized, this plan will allow a total reduction of the national power consumption of 22% and 1.3 million tons of CO_2 will be avoided. The policy pursued by Tunisia open to the regional and international cooperation, and making of its experiment an example for the developing countries. These countries have enormous renewable resources and obstacles to the greater use of these renewable energies. Among the chief obstacles are the high costs of some renewable technologies, the lack of financing mechanisms to put large scale projects and the lack of experiment and qualified workers. To overcome these energetic problems, it is advisable to: put an institutional and lawful framework in the field of energy conservation and the promotion of renewable energies, exploitation of renewable energy resources, setting up adapted means and financing mechanisms, attracting external investments and profiting themselves from the clean

development mechanism adopted by the Kyoto protocol, exchange the experiments and the knowledge with other countries and make the follow-up and the evaluation of the energy conservation projects.

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